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COPY 1 OF 2
M/021/004

September 13, 1991

Mr. Don A. Ostler
Utah Water Pollution Control Committee
Department of Health
288 North 1460 West
P.O. Box 16690
Salt Lake City, Utah 84116-0690

**SUBJECT: Groundwater Permit for Tailings Pond, Escalante, Utah**

Dear Mr. Ostler:

After receiving your letter of January 31, 1991, we spent considerable time debating how to proceed. We were concerned about the reasons for your decisions, since we believe that the issues raised had been adequately explained in our previous submittal to you. After discussion with our hydrologic and reclamation consultant, we determined that we should address the concerns of the Department again, and from another approach. Accordingly, we commissioned another study to address the issues. A copy of that study is enclosed for your review. We believe that this study verifies the conclusions contained in the reclamation plan: the potential for leaching from the tailings pond is extremely low, but if leaching did occur the impact to groundwater would be small and take thousands of years to move offsite. Thus, we continue to conclude that the probability of occurrence is small and there is a de minimis actual or potential effect on groundwater.

We also believe that we should address each of the five reasons which you used as a basis for not concurring with our previous conclusions. Our responses are as follows:

1. Table 6-8 shows 7 to more than 100 mg/Kg total cyanide in the tailings.

You are correct. The tailings pond was designed to contain the tailings material, including the residual cyanide, and was permitted to be operated and reclaimed in that manner. There have not been any actual releases to the groundwater of which we are aware. A hydrologic consultant was retained in 1984 to investigate whether or not seepage was occurring. That study showed less than a three inch wetting front in the clay liner, while the models used in the current study predict over 8 feet of wetting front. Thus the attached study is very conservative. Further, the wetting front developed before the underdrain system was opened to recycle water. Since the underdrain system was opened in 1984, there has been very low head on the liner.

The reclamation plan indicates that, based on the design of the facility and actual tests of the foundation of the pond, the potential for the cyanide to migrate from the pond is extremely low. Further, the pond will be capped with a low permeability cover. The water presently contained within the tailings is draining and is being treated, resulting in a very low (essentially zero) head on the tailings pond foundation. (The underflow during operation was about 160 gallons per minute. Presently the underdrain yields about two gallons per minute. We committed in the reclamation plan to maintain the underdrain until the tailings were drained to reduce the water contained in the tailings pond.) Thus, there will be essentially no water remaining in the tailings pond. The net result, as explained in the reclamation plan which your staff has reviewed, is that there will be essentially no potential for cyanide to migrate from the tailings pond.

2. The water level map, plate 1, shows the hydraulic gradient is toward the Northeast, an irrigated area where the ground water is used for irrigation and for culinary and stock purposes.

The hydraulic gradient in the area is to the east and northeast. However, as pointed out in the text of the reclamation plan, "In the event that any solution originating from the tailings leachate did ever reach the groundwater table, which is about 300 ft below the tailings, a time period of about 4,750 years would be required for this solution to move down-gradient 1,000 feet in the groundwater." Plate 1 also shows that the flat ground, the area which would be irrigated, is about 5-6,000 feet down-gradient. Thus, it would take over 20,000 years for the solution, assuming no attenuation in transit to and with the groundwater, to reach the area which is irrigated. As discussed in the enclosed report, there will be attenuation of cyanide in the soil and water matrix, should the solution in the pond ever penetrate the clay liner under the pond. This report shows, that when absorption is considered, it will take about 35,000 years for solute to reach the groundwater in the irrigated area.

3. Ground water in the mine area contains less than 500 mg/l dissolved solids, and therefore is worth protection.

We do not disagree. We believe that the plan is fully protective of the groundwater. The pond will be capped with a clay material, covered with subsoil and topsoil upon which vegetation will be planted for stability. With the combination of the clay cap and the convex shape of the reclaimed surface, there is little likelihood of infiltration of any consequence into the pond. Further, the underflow from the pond is currently being collected and treated, further reducing the cyanide concentration in the pond. The reclamation plan shows that the cap on the pond will result in only about 0.003 inches of water percolating through the cap per year. Thus, with the tailings moisture content at some point between 30 and 10 percent, it would take 10,000 to 40,000 years for the tailings in the pond to resaturate.

This issue was addressed again in the enclosed study. The consultant was asked to model the tailings pond under different scenarios. With implementation of the reclamation plan, using different input parameters, and utilizing an inflow through the cap over 25 times as great as in the reclamation plan (i.e., 0.08 inches per year), the HELP model shows that it would take nearly 1200 years to saturate the tailings and another 160 years for the solution to penetrate the clay liner and reach groundwater 300 feet below. This modelling effort shows that the reclamation plan as presented will protect the high quality groundwater.

4. Should cyanide be leached from the tailings pond, insufficient time has elapsed for cyanide to have reached the monitoring wells (p.8). Therefore, we do not know if leakage is occurring.

As noted in the reclamation plan and in the attached study, the calculated time for groundwater to move from beneath the impoundment to the down-gradient monitoring well is about 4,750 years. The solute travel time, due to absorption, would be anticipated to be about 11,400 years. We therefore will not expect to see any migration of cyanide from the tailings pond in any reasonable amount of time.

The best evidence of whether or not leakage is occurring is the study by Fox conducted in 1984. In this study, which was conducted after a period with at least 10 feet of head on the clay liner, showed a three inch wetting front in the two foot thick liner. Since that time, there has been very little head on the liner due to the active underdrain system that had been emplaced on top of the liner. That underdrain system is still active.

5. The HELP model (pages 4 & 5) that you used shows that the cap may achieve tight containment, but it does not leave a stable non-hazardous residual, that at some future date could be released. Therefore, obligation remains with the party that generated the tailings.

We agree that there will be some residual cyanide remaining in the tailings pond. That residual continues to be reduced due to collection and treatment of water from the underdrain system. What the reclamation plan shows, and the enclosed study supports, is that the time period for any remaining cyanide in the pond to migrate from the pond, then migrate to an area off site, is such a long time that the risk is essentially zero.

We recognize that you previously reached a decision that a permit was required for the facility. We have conducted the additional work in an effort to demonstrate our belief that incorrect assumptions were used in reaching that decision. We review the results from modelling, utilizing the same model which I believe your Department uses, and we cannot visualize an activity that will occur for which permit conditions can be structured. If an event is not likely to occur, what activity can be controlled through permit conditions? Your regulations state that permits must be submitted for facilities which "would probably result in a discharge of pollutants" to the groundwater. What level of probability is used? The likelihood is very small in this case. What permit term will be used? The modelling results show that the solute from the tailings pond, if it does migrate through a compacted clay liner, would not reach the groundwater for many generations and then in an attenuated state.

We are aware that this situation may place an unusual twist on the regulations. We are trying to reclaim a facility rather than operate it. "Modifications" which we would make are not for operation but rather to further reduce the likelihood of contaminant migration from the pond. We have no intention to place contaminants in the pond. It is therefore very difficult for us to accept obtaining a permit for something we are not planning to do or for past activities which our studies indicate are unlikely to cause an impact.

We believe that there must be a mutually agreeable solution to this situation. We have delayed responding because we believe that we should verify and confirm our previous work. We have done that and are now asking you to reconsider your decision. After having reviewed these materials, we would like to meet with you to discuss the possible resolution scenarios. In the meantime, please call if you have any questions.

Very truly yours,

Larry A. Drew
Manager - Environmental Affairs

LAD:csm

Enclosure

cc: Mack Croft

## Task 10 Report

# Cyanide Transport Modeling

# Escalante Mine
# Tailings Impoundment

COPY 1 OF 2
M/021/004

**Enterprise, Utah**

*Prepared For:*

*Hecla Mining Company*
*Coeur d'Alene, Idaho*

*Prepared By:*

*Grant, Schreiber and Associates*
*Coeur d'Alene, Idaho*

*June 28, 1991*

*Project No. 610449*

Kevin S. Rauch
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*Grant, Schreiber and Associates*
Engineering • Hydrology • Management
Coeur d'Alene • Denver • Little Rock

Task 10 Report

# Cyanide Transport Modeling

# Escalante Mine Tailings Impoundment

## Enterprise, Utah

*Prepared For:*

*Hecla Mining Company*
*Coeur d'Alene, Idaho*

*Prepared By:*

*Grant, Schreiber and Associates*
*Coeur d'Alene, Idaho*

*June 28, 1991*

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# 1. INTRODUCTION

As a follow-up to the Escalante Mine Reclamation Plan, Grant, Schreiber and Associates (GSA) has completed additional studies of the potential for leachate and the movement of cyanide from the tailings impoundment. The work includes modeling of the impoundment to determine the length of time for liquid to penetrate the pond liner and subsequently reach the water table assuming:

- continued use of the pond,
- no reclamation of the pond, and
- reclamation of the pond, as proposed.

In addition, GSA has used available information regarding cyanide attenuation/degradation to assess potential impacts to the local ground-water system. This work is summarized in the following sections.

# 2. PREVIOUS INVESTIGATION

An investigation was conducted by Fox Consultants, Inc. (Fox) in 1984 to evaluate the potential for seepage migration through the compacted liner and natural foundation soils. The investigation included:

- drilling and sampling at one location within the tailings impoundment to provide a vertical profile of the tailings, compacted liner, and natural foundation materials,
- conducting a laboratory testing program on the retrieved samples to measure moisture content, dry density, specific gravity, and permeability, and
- estimating the potential for seepage migration through the liner during:
  - the original design life of the tailings pond, and
  - a possible extended tailings pond life, including an additional 10 to 15 feet of deposited tailings.

Based upon the field and laboratory investigations, Fox concluded that:

- After approximately 14 months under an average of 10 feet of saturation and an additional 20 months following the activation of the underdrain system, the wetting front did not appear to have penetrated through the liner or into the foundation. The wetting front may have progressed 3 inches, at the most, into the liner, prior to the activation of the underdrain system.

- Theoretical predictions of the time required for the wetting front to penetrate 3 inches into the liner were several orders of magnitude faster than indicated by field observations.
- The underdrain system appeared to have eliminated or significantly reduced the phreatic surface within the tailings, which greatly lowers the potential for seepage migration through the compacted liner.

Based upon these facts and the great depth to the water table, Fox concluded that the potential for seepage migration through the liner and foundation to the ground-water table during and after the design life of the impoundment is extremely small.

# 3. WATER MOVEMENT

To conduct the present investigation, GSA used the Hydrologic Evaluation of Landfill Performance (HELP) Model (Schroeder, et al., 1983, and Schroeder, 1988) to simulate movement of water through the tailings impoundment for the following conditions:

- during operation,
- after operation without reclamation, and
- with reclamation, as proposed.

The HELP Model requires climatologic data including precipitation, temperature, and solar radiation. For each of the three conditions, GSA used synthetic climate data for Milford, Utah. The synthetic temperature and precipitation calculated by the HELP model were based upon the local mean monthly temperature and precipitation data.

The modeling that GSA performed for the reclamation plan (GSA, 1990) used climatologic data collected at Cedar City, Utah, from 1974 through 1978. This data set was provided with the HELP model. Since this data set only covered a five-year period, GSA opted to use synthetically generated data for Milford, Utah, for the present study. This data set is also provided with the HELP model. The use of these data allowed GSA to conduct the simulation for a period of up to 20 years.

The average precipitation at Cedar City during the period from 1974 through 1978 was 9.76 inches, compared to 10.47 inches for the 20 years of the synthetic data. According to Section A of Notice of Intention to Commence Mining Operations (Ranchers, 1980), the total precipitation is 10 to 15 inches per year. Thus, the synthetic data are within this range. The following sections summarize the HELP model simulations.

## 3.1 During Operations

GSA used information from previous reports to simulate the tailings impoundment during operations. According to the report by Wright Engineers (Wright, 1980), water was to be deposited in the pond at a rate of 160 gpm or 247.5 acre-feet per year. This rate of inflow is equivalent to approximately 0.15 inches per day, spread over the entire surface area of the pond. To incorporate this inflow into the HELP model, the 0.15 inches per day of water was added to the daily precipitation for the first 10 years of the simulation. For the purpose of the simulation, it was assumed that the average depth of the tailings was 30 feet (Drawing No. 11359 from the Reclamation Plan). The soil profile of the tailings impoundment used to simulate this condition is shown in Table 1. The thickness, porosity, hydraulic conductivity, and initial water content were obtained from Fox Reports (1980 and 1984).

Table 1. Soil profile for operational and pre-reclamation condition.

| Layer | Material | Thickness (inches) | Layer Type | Porosity | Hydraulic Conductivity cm/sec | Initial Water Content |
|---|---|---|---|---|---|---|
| 1 | Tailings | 360 | Vertical Percolation | 0.49 | $1.9X10^{-5}$ | 30.0% |
| 2 | Underdrain | 12 | Lateral Drainage | 0.41 | $1.0X10^{-3}$ | 13.2% |
| 3 | Clay Liner | 24 | Barrier | 0.41 | $5.67X10^{-7}$ | 15.1% |
| 4 | Foundation Soil | 3600 | Vertical Percolation | 0.31 | $2.44X10^{-5}$ | 5.7% |

Table 2 shows the results of the simulation for the 10-years of operation. The precipitation, including water from the mill, ranged from 61.55 to 70.46 inches per year, with an average of 65.67 inches. Evapotranspiration ranged

DURING OPERATIONS

from 46.341 to 49.682 inches per year, with an average of 47.698 inches. This loss represents nearly three quarters of the water entering the pond. Flow from the underdrain, which was returned to the mill, averaged 7.17 inches per year during the 10-year period of operations. Flow from the underdrain began in June of the third year and reached a peak of 14.11 inches in the seventh year. Over the entire operating period, the underdrain flow represented nearly 11 percent of the water entering the pond. However, during years 6 through 10, the underdrain removed an average of 17.3 percent of the total water input, including over 20 percent in the seventh year.

The model predicts that water will begin percolating from the liner in June of the third year, which is the same time that the underdrain begins flowing. The liner maintains a relatively constant seepage of approximately 7.25 inches for years 4 through 10. Percolation through the foundation soils and into ground water occurs every year during the simulation. The percolation to ground water during the first two years is 0.0352 inches. Since both the underdrain and liner seepage were zero, the percolation to ground water, during this time, is the result of natural recharge. The amount of percolation to ground water subsequently increases in each of the following years.

## 3.2 After Operations With No Reclamation

The HELP model was used to simulate the tailings impoundment after operations were ceased. This simulation was performed for the 10 years immediately following operation of the impoundment. Table 2 shows that, during this period, the precipitation ranged from 5.22 to 16.32 inches, with an average of 10.01 inches. Evapotranspiration during this period ranged from 5.515 to 16.722, with an average of 10.047 inches. This accounts for a loss of over 100 percent of the water input into the system. During this time, however, there is still moisture in the soil layers that migrates through the liner and percolates to ground water. The amount of percolation through the liner is rapidly decreasing during this period, while the percolation to ground water is slowly increasing as water moves downward through the unsaturated zone.

Table 2. HELP Model results for operational and pre-reclamation conditions.

| Year | Precipitation (inches) | Runoff (inches) | Evapotrans (inches) | Underdrain (inches) | Percolation Liner (inches) | Percolation Groundwater (inches) |
|---|---|---|---|---|---|---|
| *During operations* | | | | | | |
| 1 | 62.99 | 0.000 | 47.065 | 0.0000 | 0.0000 | 0.0352 |
| 2 | 64.64 | 0.000 | 48.269 | 0.0000 | 0.0000 | 0.0352 |
| 3 | 65.98 | 0.000 | 46.341 | 0.0413 | 3.1375 | 0.0361 |
| 4 | 61.55 | 0.000 | 47.023 | 5.9464 | 7.1791 | 0.0436 |
| 5 | 64.58 | 0.000 | 48.132 | 7.3776 | 7.1866 | 0.0540 |
| 6 | 70.46 | 0.000 | 49.682 | 11.9536 | 7.2816 | 0.0665 |
| 7 | 70.20 | 0.000 | 47.673 | 14.1143 | 7.3240 | 0.0812 |
| 8 | 66.72 | 0.000 | 48.565 | 11.9268 | 7.2999 | 0.0985 |
| 9 | 62.25 | 0.000 | 47.724 | 9.1831 | 7.2225 | 0.1177 |
| 10 | 67.34 | 0.000 | 46.509 | 11.2019 | 7.2655 | 0.1400 |
| Average | 65.67 | 0.000 | 47.698 | 7.1745 | 5.3897 | 0.0708 |
| St. Dev | 3.083 | 0.000 | 1.017 | 5.4693 | 3.1171 | 0.0375 |
| Percent | 100.00 | 0.00 | 72.63 | 10.92 | 8.21 | 0.11 |
| *After operations, with no reclamation* | | | | | | |
| 11 | 8.79 | 0.000 | 10.556 | 4.2219 | 6.8600 | 0.1650 |
| 12 | 12.15 | 0.000 | 10.907 | 0.0062 | 3.7856 | 0.1861 |
| 13 | 12.96 | 0.000 | 14.181 | 0.0023 | 2.3236 | 0.1972 |
| 14 | 7.68 | 0.000 | 6.902 | 0.0012 | 1.6687 | 0.2050 |
| 15 | 8.78 | 0.000 | 8.528 | 0.0007 | 1.2816 | 0.2107 |
| 16 | 9.02 | 0.000 | 8.727 | 0.0005 | 1.0408 | 0.2156 |
| 17 | 16.32 | 0.000 | 16.722 | 0.0003 | 0.8709 | 0.2185 |
| 18 | 12.00 | 0.000 | 12.272 | 0.0002 | 0.7495 | 0.2213 |
| 19 | 5.22 | 0.000 | 5.515 | 0.0002 | 0.6572 | 0.2236 |
| 20 | 7.20 | 0.000 | 6.161 | 0.0001 | 0.5862 | 0.2261 |
| Average | 10.01 | 0.000 | 10.047 | 0.4234 | 1.9824 | 0.2069 |
| St. Dev | 3.288 | 0.000 | 3.608 | 1.3347 | 1.9747 | 0.0193 |
| Percent | 100.00 | 0.00 | 100.35 | 4.23 | 19.80 | 2.07 |
| *Years 1 through 20* | | | | | | |
| Average | 37.84 | 0.000 | 28.873 | 3.7989 | 3.6860 | 0.1389 |
| St. Dev | 28.721 | 0.000 | 19.486 | 5.1969 | 3.0830 | 0.0756 |
| Percent | 100.00 | 0.00 | 76.30 | 10.04 | 9.74 | 0.37 |

## 3.3 After Reclamation

GSA also used the HELP model to simulate the tailings impoundment after reclamation. The impoundment was simulated using the seven layers proposed in the reclamation plan. The configuration and properties of these layers are shown in Table 3. Layers 1 through 3 represent the topsoil, subsoil, and clay cap, respectively. The properties of these layers were selected based upon typical values for the soils present at the site. Layers 4 through 7 represent the tailings, underdrain, clay liner, and foundation soil, respectively.

Table 3. Soil profile for the reclaimed tailings impoundment.

| Layer | Material | Thickness (inches) | Layer Type | Porosity | Hydraulic Conductivity cm/sec | Initial Water Content |
|---|---|---|---|---|---|---|
| 1 | Topsoil | 4 | Vertical Percolation | 0.40 | $1.2X10^{-4}$ | 5.0% |
| 2 | Subsoil | 14 | Lateral Drainage | 0.42 | $1.0X10^{-5}$ | 5.0% |
| 3 | Clay Cap | 6 | Barrier | 0.43 | $1.0X10^{-7}$ | 10.0% |
| 4 | Tailings | 360 | Vertical Percolation | 0.49 | $1.9X10^{-5}$ | 30.0% |
| 5 | Underdrain | 12 | Lateral Drainage | 0.41 | $1.0X10^{-3}$ | 13.2% |
| 6 | Clay Liner | 24 | Barrier | 0.41 | $5.67X10^{-7}$ | 15.1% |
| 7 | Foundation Soil | 3600 | Vertical Percolation | 0.31 | $2.44X10^{-5}$ | 5.7% |

Table 4 shows the results of the simulation for a period of 20 years after reclamation. The precipitation during this period ranged from 5.22 to 16.32 inches, with an average of 10.47 inches. Surface runoff from the cap ranged from 0.002 to 1.396 inches, with an average of 0.367 inches. This accounts for a loss of 3.5 percent of the water input to the system. Evapotranspiration during this period ranged from 5.552 to 15.482 inches, with an average of 9.945 inches. This results in a loss of over 95 percent of the water entering the system. The model also shows an average of 0.0839 inches per year penetrating the 6-inch clay cap and entering the tailings. Assuming that the tailings were initially dry, it would take approximately 1,660 years to saturate the tailings at this rate of seepage. If the tailings moisture is 30 percent, as observed during operations, it will take approximately 270 years to saturate the tailings. Since the tailings have been draining since operations were ceased, the water content will be much less than 30 percent. For instance, if the water content of the tailings was reduced to 10 percent, the time required to saturate the tailings at an inflow rate of 0.0839 inches per year is nearly 1,200 years.

Most importantly, the model shows <u>no</u> liquid reaching the underdrain, percolating through the liner, or percolating to ground water during the 20-year period following reclamation. The lack of ground-water recharge, compared to cases without reclamation, is attributed to the reduced water supply resulting from:

- the absence of the process water entering the impoundment, and
- reduced infiltration resulting from encapsulation of the tailings.

Table 4. HELP Model results for Escalante Mine after reclamation.

| Year | Precipitation (inches) | Runoff (inches) | Evapotrans (inches) | Cap Drain (inches) | Cap Percolation (inches) | Underdrain (inches) | Percolation | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Liner (inches) | Groundwater (inches) |
| 1 | 8.24 | 0.120 | 7.408 | 0.0000 | 0.0094 | 0.0000 | 0.0000 | 0.0000 |
| 2 | 9.89 | 0.130 | 9.302 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3 | 11.23 | 0.177 | 10.960 | 0.0001 | 0.3516 | 0.0000 | 0.0000 | 0.0000 |
| 4 | 6.80 | 0.002 | 7.371 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 5 | 9.83 | 0.315 | 8.199 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 6 | 15.71 | 0.648 | 15.482 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7 | 15.45 | 0.588 | 14.503 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 8 | 11.97 | 0.436 | 11.411 | 0.0000 | 0.1912 | 0.0000 | 0.0000 | 0.0000 |
| 9 | 7.50 | 0.007 | 8.679 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10 | 12.59 | 1.396 | 10.264 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11 | 8.79 | 0.049 | 9.551 | 0.0000 | 0.2531 | 0.0000 | 0.0000 | 0.0000 |
| 12 | 12.15 | 0.243 | 10.797 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 13 | 12.96 | 0.645 | 12.912 | 0.0002 | 0.5022 | 0.0000 | 0.0000 | 0.0000 |
| 14 | 7.68 | 0.470 | 6.778 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 15 | 8.78 | 0.145 | 8.338 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 16 | 9.02 | 0.065 | 8.099 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 17 | 16.32 | 1.341 | 15.739 | 0.0002 | 0.3713 | 0.0000 | 0.0000 | 0.0000 |
| 18 | 12.00 | 0.447 | 11.595 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 19 | 5.22 | 0.039 | 5.552 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20 | 7.20 | 0.074 | 5.966 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Average | 10.47 | 0.367 | 9.945 | 0.0000 | 0.0839 | 0.0000 | 0.0000 | 0.0000 |
| St Dev | 3.137 | 0.404 | 2.991 | 0.0001 | 0.1579 | 0.0000 | 0.0000 | 0.0000 |
| Percent | 100.00 | 3.50 | 95.02 | 0.00 | 0.80 | 0.00 | 0.00 | 0.00 |

# 4. CYANIDE MOVEMENT

GSA used information on cyanide movement, attenuation, and degradation from a study by Resource Recovery and Conservation Consultants ($R^2C^2$, 1989) to investigate the potential impacts of cyanide at the Escalante Site. Among the information developed during the course of the $R^2C^2$ study was a model of cyanide solute transport through a clay lined pond. The model was developed at Colorado State University by Simon Lorentz and David McWhorter.

GSA used this model to estimate the time required for liquid and solute to reach the ground-water table, which is approximately 300 feet below the bottom of the impoundment. Data contained in the reclamation plan and Fox Reports (1980 and 1984), supplemented with data from the $R^2C^2$ study, were used to model the system. The parameters required by the model, and the values for these parameters, are briefly summarized below:

IS THIS BASED ON MEASUREMENTS TAKEN WHILE THE MINE WAS STILL BEING DE-WATERED?

- Depth to the water table ($D_f$) - 300 feet (Fox, 1980 and GSA, 1990).
- Depth of Ponding ($D_w$) - considered to be the maximum daily head on the pond liner (2.3 inches), as calculated by the HELP model. Other values were used to simulate extreme conditions.
- Thickness of the clay liner ($D_l$) - 2 feet (Fox 1980).
- Hydraulic conductivity of the liner ($K_l$) - $5.67 \times 10^{-7}$ cm/sec (Fox, 1980).
- Hydraulic conductivity of the foundation ($K_o$) - $2.44 \times 10^{-5}$ cm/s (Fox, 1980)
- Alpha parameter of the foundation ($\alpha$) - defines the unsaturated hydraulic conductivity of the foundation soil ($K_f$) as a function of $K_o$ and matric potential (h) as: $K_f = K_o e^{-\alpha h}$. Values of 0.03, 0.05, and 0.055 $cm^{-1}$ were selected for comparison, based upon data presented by $R^2C^2$ (1989).
- Distribution Coefficient ($K_d$) - Values of 0.3 and 0.7 $cm^3/g$ were selected for comparison, based upon data presented by $R^2C^2$ (1989).
- Bulk Density ($\rho_b$) - 1.45 $g/cm^3$ (Fox, 1984).
- Henry's Law Constant ($K_H$) - 0.0043 ($R^2C^2$, 1989).
- Residual Water Content ($\theta_r$) - Values of 0.10, 0.15, and 0.20 were selected for comparison, based upon data presented by $R^2C^2$ (1989).
- Saturated water content ($\theta_s$) - 0.31 (same as porosity).

$K_d$ - DISTRIBUTION COEFFICIENT

$\alpha$ - ALPHA PARAMETER OF THE FOUNDATION

- Tortuosity Constant (m) - Values of 0, 1, and 2 were selected for comparison, based upon data presented by $R^2C^2$ (1989).
- Concentration of Effluent ($C_o$) - The concentrations of cyanide in two water samples collected from the underdrain on October 4, 1990 (GSA, 1990) were 186 and 191 mg/l. Thus, a representative value of $C_o$=190 mg/l was used in the model.

Table 5 shows the results of the CSU model for 14 cases. The 14 cases represent a sensitivity analysis that was performed because of the uncertainty of some of the parameters. These parameters include $K_d$, $\alpha$, $\theta_r$, m, and $D_w$. The values used for these parameters were estimated based upon guidance provided in the $R^2C^2$ report. For Cases 2 through 14, the shaded value in Table 5 has been changed, while holding the other parameters constant.

Case 1 represents GSA's best estimate of the actual conditions at the Escalante site. This case results in a required time of nearly 59,600 days, or more that 160 years, for the solute to reach ground water. At this time, the model begins computing the mass loading of cyanide in g/m² to the aquifer. A drawback to the model is the assumption that the cyanide concentration in the plume is constant. Thus, the mass loading to the aquifer increases linearly with time, based upon the effluent concentration ($C_o$) and flow rate. Therefore, the model is not accounting for the degradation of cyanide.

The parameters that have the greatest affect on the time for the solute to reach groundwater are $K_d$ (Cases 1,2, and 3) and $\alpha$ (Cases 1, 4, and 5). Case 3 ($K_d$=0), which represents no adsorption of the solute onto the solid matrix, is equivalent to the movement of the water through the foundation soil. The predicted time for the solute to reach ground water for this case is nearly 20,900 days or 57 years. Increasing $K_d$ from 0 to 0.7 increases this time to over 300 years. Decreasing $\alpha$ from 0.05 to 0.03 decreased the travel time by approximately 32 years, while increasing $\alpha$ from 0.05 to 0.055 increased the travel time by 6 years. Changing $\theta_r$ and m resulted in relatively small changes in the travel time, as evidenced by Cases 6 through 9. Changing $D_w$ over the range of values indicated by the HELP model showed small changes in the travel time (Cases 10 and 11). Cases 12 through 14 shows the effect of a larger head (1 to 10 feet) on the liner. Case 12 represents the underdrain layer under a saturated condition (1 foot of head on the liner). Case 13 represents approximately 3 feet of head on the liner. These two cases resulted in solute travel times of 112 and

Table 5. Modeling Results from CSU Cyanide Transport Model.

BEST ESTIMATE OF ACTUAL CONDITIONS

## Case 1

| Parameter | | Time | Mass Loading | Solute Depth |
|---|---|---|---|---|
| Df, m | 91.5 | 100 | 0 | 0.92 |
| Dw, m | 0.06 | 1000 | 0 | 1.83 |
| Dl, m | 0.6 | 10000 | 0 | 15.55 |
| Kl, cm/s | 5.67E-07 | 20000 | 0 | 31.11 |
| Ko, cm/s | 2.44E-05 | 40000 | 0 | 62.22 |
| Alpha | 0.05 | 50000 | 0 | 76.86 |
| Kd, cm3/g | 0.3 | 59500 | 0 | 91.5 |
| Pb, g/cm3 | 1.45 | 60000 | 69.9 | 91.5 |
| Kh | 0.0043 | 80000 | 3989.9 | 91.5 |
| Θr | 0.1 | 100000 | 7910 | 91.5 |
| Θs | 0.3 | 150000 | 17710 | 91.5 |
| m | 1 | 200000 | 27510 | 91.5 |
| Co, mg/l | 190 | | | |
| Travel time* | 59644 | | | |

## Case 2

| Parameter | | Time | Mass Loading | Solute Depth |
|---|---|---|---|---|
| Df, m | 91.5 | 100 | 0 | 0.92 |
| Dw, m | 0.06 | 1000 | 0 | 0.92 |
| Dl, m | 0.6 | 10000 | 0 | 9.15 |
| Kl, cm/s | 5.67E-07 | 20000 | 0 | 17.38 |
| Ko, cm/s | 2.44E-05 | 40000 | 0 | 33.85 |
| Alpha | 0.05 | 60000 | 0 | 49.41 |
| Kd, cm3/g | 0.7 | 80000 | 0 | 65.88 |
| Pb, g/cm3 | 1.45 | 100000 | 0 | 82.35 |
| Kh | 0.0043 | 110000 | 0 | 90.59 |
| Θr | 0.1 | 111000 | 0 | 91.5 |
| Θs | 0.3 | 111500 | 37.1 | 91.5 |
| m | 1 | 120000 | 1703.2 | 91.5 |
| Co, mg/l | 190 | 150000 | 7583.2 | 91.5 |
| Travel time* | 111310 | 200000 | 17383.2 | 91.5 |

## Case 3

| Parameter | | Time | Mass Loading | Solute Depth |
|---|---|---|---|---|
| Df, m | 91.5 | 100 | 0 | 0.92 |
| Dw, m | 0.06 | 1000 | 0 | 5.49 |
| Dl, m | 0.6 | 10000 | 0 | 44.83 |
| Kl, cm/s | 5.67E-07 | 20000 | 0 | 87.84 |
| Ko, cm/s | 2.44E-05 | 20900 | 1.3 | 91.5 |
| Alpha | 0.05 | 25000 | 804.9 | 91.5 |
| Kd, cm3/g | 0 | 30000 | 1784.9 | 91.5 |
| Pb, g/cm3 | 1.45 | 40000 | 3745 | 91.5 |
| Kh | 0.0043 | 50000 | 5705 | 91.5 |
| Θr | 0.1 | 100000 | 15505 | 91.5 |
| Θs | 0.3 | 200000 | 35105 | 91.5 |
| m | 1 | | | |
| Co, mg/l | 190 | | | |
| Travel time* | 20893 | | | |

## Case 4

| Parameter | | Time | Mass Loading | Solute Depth |
|---|---|---|---|---|
| Df, m | 91.5 | 100 | 0 | 0.92 |
| Dw, m | 0.06 | 1000 | 0 | 2.75 |
| Dl, m | 0.6 | 10000 | 0 | 20.13 |
| Kl, cm/s | 5.67E-07 | 20000 | 0 | 38.43 |
| Ko, cm/s | 2.44E-05 | 40000 | 0 | 76.86 |
| Alpha | 0.03 | 47000 | 0 | 90.59 |
| Kd, cm3/g | 0.3 | 48000 | 33.7 | 91.5 |
| Pb, g/cm3 | 1.45 | 50000 | 526.8 | 91.5 |
| Kh | 0.0043 | 100000 | 12854 | 91.5 |
| Θr | 0.1 | 150000 | 25181 | 91.5 |
| Θs | 0.3 | 200000 | 37509 | 91.5 |
| m | 1 | | | |
| Co, mg/l | 190 | | | |
| Travel time* | 47863 | | | |

*Time in days for solute front to reach ground water.

Table 5. Modeling Results from CSU Cyanide Transport Model (continued).

### Case 5

| Parameter | | Time | Mass Loading | Solute Depth |
|---|---|---|---|---|
| Df, m | 91.5 | 100 | 0 | 0.92 |
| Dw, m | 0.06 | 1000 | 0 | 1.83 |
| Dl, m | 0.6 | 10000 | 0 | 15.55 |
| Kl, cm/s | 5.67E-07 | 20000 | 0 | 30.19 |
| Ko, cm/s | 2.44E-05 | 40000 | 0 | 59.47 |
| Alpha | 0.055 | 60000 | 0 | 88.76 |
| Kd, cm3/g | 0.3 | 61000 | 0 | 90.59 |
| Pb, g/cm3 | 1.45 | 61900 | 1.1 | 91.5 |
| Kh | 0.0043 | 70000 | 1528.6 | 91.5 |
| Θr | 0.1 | 100000 | 7186 | 91.5 |
| Θs | 0.3 | 150000 | 16615 | 91.5 |
| m | 1 | 200000 | 26044 | 91.5 |
| Co, mg/l | 190 | | | |
| Travel time* | 61894 | | | |

### Case 6

| Parameter | | Time | Mass Loading | Solute Depth |
|---|---|---|---|---|
| Df, m | 91.5 | 100 | 0 | 0.92 |
| Dw, m | 0.06 | 1000 | 0 | 1.83 |
| Dl, m | 0.6 | 10000 | 0 | 15.55 |
| Kl, cm/s | 5.67E-07 | 20000 | 0 | 30.19 |
| Ko, cm/s | 2.44E-05 | 40000 | 0 | 60.39 |
| Alpha | 0.05 | 60000 | 0 | 90.59 |
| Kd, cm3/g | 0.3 | 61000 | 0 | 91.5 |
| Pb, g/cm3 | 1.45 | 62000 | 182.7 | 91.5 |
| Kh | 0.0043 | 80000 | 3710.7 | 91.5 |
| Θr | 0.15 | 100000 | 7630.7 | 91.5 |
| Θs | 0.3 | 150000 | 17430.8 | 91.5 |
| m | 1 | 200000 | 27231 | 91.5 |
| Co, mg/l | 190 | | | |
| Travel time* | 61068 | | | |

### Case 7

| Parameter | | Time | Mass Loading | Solute Depth |
|---|---|---|---|---|
| Df, m | 91.5 | 100 | 0 | 0.92 |
| Dw, m | 0.06 | 1000 | 0 | 1.83 |
| Dl, m | 0.6 | 10000 | 0 | 15.55 |
| Kl, cm/s | 5.67E-07 | 20000 | 0 | 30.19 |
| Ko, cm/s | 2.44E-05 | 40000 | 0 | 59.47 |
| Alpha | 0.05 | 60000 | 0 | 88.76 |
| Kd, cm3/g | 0.3 | 62000 | 0 | 91.5 |
| Pb, g/cm3 | 1.45 | 62500 | 1.5 | 91.5 |
| Kh | 0.0043 | 80000 | 3431.5 | 91.5 |
| Θr | 0.2 | 100000 | 7351.5 | 91.5 |
| Θs | 0.3 | 150000 | 17151.6 | 91.5 |
| m | 1 | 200000 | 26951.7 | 91.5 |
| Co, mg/l | 190 | | | |
| Travel time* | 62493 | | | |

### Case 8

| Parameter | | Time | Mass Loading | Solute Depth |
|---|---|---|---|---|
| Df, m | 91.5 | 100 | 0 | 0.92 |
| Dw, m | 0.06 | 1000 | 0 | 1.83 |
| Dl, m | 0.6 | 10000 | 0 | 16.47 |
| Kl, cm/s | 5.67E-07 | 20000 | 0 | 32.02 |
| Ko, cm/s | 2.44E-05 | 40000 | 0 | 64.05 |
| Alpha | 0.05 | 57000 | 0 | 91.5 |
| Kd, cm3/g | 0.3 | 57600 | 13.6 | 91.5 |
| Pb, g/cm3 | 1.45 | 60000 | 484 | 91.5 |
| Kh | 0.0043 | 80000 | 4404 | 91.5 |
| Θr | 0.1 | 100000 | 8324.1 | 91.5 |
| Θs | 0.3 | 150000 | 18124.2 | 91.5 |
| m | 0 | 200000 | 27924.3 | 91.5 |
| Co, mg/l | 190 | | | |
| Travel time* | 57531 | | | |

*Time in days for solute front to reach ground water.

Table 5. Modeling Results from CSU Cyanide Transport Model (continued).

### Case 9

| Parameter | | Time | Mass Loading | Solute Depth |
|---|---|---|---|---|
| Df, m | 91.5 | 100 | 0 | 0.92 |
| Dw, m | 0.06 | 1000 | 0 | 1.83 |
| Dl, m | 0.6 | 10000 | 0 | 15.55 |
| Kl, cm/s | 5.67E−07 | 20000 | 0 | 30.19 |
| Ko, cm/s | 2.44E−05 | 40000 | 0 | 60.39 |
| Alpha | 0.05 | 60000 | 0 | 90.59 |
| Kd, cm3/g | 0.3 | 61000 | 26.3 | 91.5 |
| Pb, g/cm3 | 1.45 | 80000 | 3750 | 91.5 |
| Kh | 0.0043 | 100000 | 7670 | 91.5 |
| θr | 0.1 | 150000 | 17470 | 91.5 |
| θs | 0.3 | 200000 | 27270 | 91.5 |
| m | 2 | | | |
| Co, mg/l | 190 | | | |
| Travel time* | 60866 | | | |

### Case 10

| Parameter | | Time | Mass Loading | Solute Depth |
|---|---|---|---|---|
| Df, m | 91.5 | 100 | 0 | 0.92 |
| Dw, m | 0.03 | 1000 | 0 | 1.83 |
| Dl, m | 0.6 | 10000 | 0 | 15.55 |
| Kl, cm/s | 5.67E−07 | 20000 | 0 | 31.11 |
| Ko, cm/s | 2.44E−05 | 40000 | 0 | 60.39 |
| Alpha | 0.05 | 60000 | 0 | 90.59 |
| Kd, cm3/g | 0.3 | 61000 | 30.7 | 91.5 |
| Pb, g/cm3 | 1.45 | 80000 | 3678.5 | 91.5 |
| Kh | 0.0043 | 100000 | 7518.3 | 91.5 |
| θr | 0.1 | 150000 | 17118 | 91.5 |
| θs | 0.3 | 200000 | 26717 | 91.5 |
| m | 1 | | | |
| Co, mg/l | 190 | | | |
| Travel time* | 60840 | | | |

### Case 11

| Parameter | | Time | Mass Loading | Solute Depth |
|---|---|---|---|---|
| Df, m | 91.5 | 100 | 0 | 0.92 |
| Dw, m | 0 | 1000 | 0 | 1.83 |
| Dl, m | 0.6 | 10000 | 0 | 15.55 |
| Kl, cm/s | 5.67E−07 | 20000 | 0 | 30.19 |
| Ko, cm/s | 2.44E−05 | 40000 | 0 | 59.47 |
| Alpha | 0.05 | 60000 | 0 | 88.76 |
| Kd, cm3/g | 0.3 | 62000 | 0 | 91.5 |
| Pb, g/cm3 | 1.45 | 63000 | 172.5 | 91.5 |
| Kh | 0.0043 | 80000 | 3368.3 | 91.5 |
| θr | 0.1 | 100000 | 7128.1 | 91.5 |
| θs | 0.3 | 150000 | 16527.5 | 91.5 |
| m | 1 | 200000 | 25927 | 91.5 |
| Co, mg/l | 190 | | | |
| Travel time* | 62083 | | | |

### Case 12

INCREASE IN HEAD

| Parameter | | Time | Mass Loading | Solute Depth |
|---|---|---|---|---|
| Df, m | 91.5 | 100 | 0 | 0.92 |
| Dw, m | 0.305 | 1000 | 0 | 2.75 |
| Dl, m | 0.6 | 10000 | 0 | 22.87 |
| Kl, cm/s | 5.67E−07 | 20000 | 0 | 45.75 |
| Ko, cm/s | 2.44E−05 | 30000 | 0 | 67.71 |
| Alpha | 0.05 | 40000 | 0 | 90.59 |
| Kd, cm3/g | 0.3 | 41000 | 63.1 | 91.5 |
| Pb, g/cm3 | 1.45 | 50000 | 2125.5 | 91.5 |
| Kh | 0.0043 | 60000 | 4417.1 | 91.5 |
| θr | 0.1 | 80000 | 9000.3 | 91.5 |
| θs | 0.3 | 100000 | 13583.5 | 91.5 |
| m | 1 | 150000 | 25041.5 | 91.5 |
| Co, mg/l | 190 | 200000 | 36449.5 | 91.5 |
| Travel time* | 40724 | | | |

*Time in days for solute front to reach ground water.

Table 5. Modeling Results from CSU Cyanide Transport Model (continued).

INCREASE IN HEAD

**Case 13**

| Parameter | | Time | Mass Loading | Solute Depth |
|---|---|---|---|---|
| Df, m | 91.5 | 100 | 0 | 0.92 |
| Dw, m | 1 | 1000 | 0 | 2.75 |
| Dl, m | 0.6 | 10000 | 0 | 25.62 |
| Kl, cm/s | 5.67E-07 | 20000 | 0 | 50.32 |
| Ko, cm/s | 2.44E-05 | 30000 | 0 | 75.95 |
| Alpha | 0.05 | 36000 | 0 | 90.59 |
| Kd, cm3/g | 0.3 | 37000 | 133.3 | 91.5 |
| Pb, g/cm3 | 1.45 | 40000 | 1111.4 | 91.5 |
| Kh | 0.0043 | 60000 | 7632.1 | 91.5 |
| Θr | 0.1 | 80000 | 14152.8 | 91.5 |
| Θs | 0.3 | 100000 | 20673.6 | 91.5 |
| m | 1 | 150000 | 36975.4 | 91.5 |
| Co, mg/l | 190 | 200000 | 53277.2 | 91.5 |
| Travel time* | 36591 | | | |

**Case 14**

| Parameter | | Time | Mass Loading | Solute Depth |
|---|---|---|---|---|
| Df, m | 91.5 | 100 | 0 | 0.92 |
| Dw, m | 3.048 | 1000 | 0 | 5.49 |
| Dl, m | 0.6 | 10000 | 0 | 47.58 |
| Kl, cm/s | 5.67E-07 | 19500 | 0 | 91.5 |
| Ko, cm/s | 2.44E-05 | 20000 | 236.9 | 91.5 |
| Alpha | 0.05 | 40000 | 12709.3 | 91.5 |
| Kd, cm3/g | 0.3 | 60000 | 25181.8 | 91.5 |
| Pb, g/cm3 | 1.45 | 80000 | 37654.3 | 91.5 |
| Kh | 0.0043 | 100000 | 50126.8 | 91.5 |
| Θr | 0.1 | 150000 | 81307.9 | 91.5 |
| Θs | 0.3 | 200000 | 112489. | 91.5 |
| m | 1 | | | |
| Co, mg/l | 190 | | | |
| Travel time | 19602 | | | |

*Time in days for solute front to reach ground water.

100 years, respectively. Case 14 represents the start of operations at the mine when the impoundment operated at an average saturation of 10 feet for 14 months prior to the activation of the underdrain. Under a constant saturation of 10 feet, the time required for the solute to reach the water table is approximately 54 years. After 14 months at a saturated depth of 10 feet, the predicted depth of the solute front is 8.4 feet. However, this is much greater than the actual conditions that were observed by Fox in 1984, as described in Section 2.

# 5. CYANIDE IMPACT

The calculated travel time for ground-water to move from beneath the impoundment to the downgradient monitoring well, located approximately 1,000 feet from the impoundment, is 4,750 years (GSA, 1990). If adsorption is considered, the time for solute to reach the monitoring well will be much greater. The retardation factor, $R_d$, can be used to compute the solute travel time with the presence of adsorption. The retardation factor is defined as: $R_d = 1 + (\rho_b/\phi)K_d$, where $\phi$ is the total porosity. For $\rho_b$=1.45 g/cm$^3$, $\phi$=0.31, and $K_d$=0.3, $R_d$ is equal to 2.4. Thus, the solute travel time will be 2.4 times the ground-water gravel time, or 11,400 years to reach the downgradient monitoring well. As shown in Figure 1, the nearest downgradient wells (WL-14 and WQ-2) are approximately 6,000 feet from the tailings impoundment. Using water level data from wells TMW-2 and D-2 to calculate the gradient and $K_o$=2.44X10$^{-5}$, the travel time to wells WL-14 and WQ-2 is approximately 14,600 years. Considering the affect of adsorption, the time required for solute to reach these wells is more than 35,000 years.

As stated in Section 4, GSA's best estimate of the travel time of solute through the unsaturated zone is over 160 years. This travel time through the unsaturated zone is insignificant when compared to the magnitude of the ground water and solute travel times. However, according to the $R^2C^2$ study, cyanide degradation can occur in both the saturated and unsaturated zones, but particularly in the unsaturated zone. Thus, the 160-year solute travel time through the unsaturated zone may provide a significant reduction in cyanide concentration.

Cyanide attenuation/degradation can occur by many mechanisms including: volatilization, chelation, precipitation, adsorption, oxidation to cyanate, and biodegradation. In a large column test that was operated for 81 days, $R^2C^2$ obtained the following results: — ¿ A TEST ON ESCALANTE MTLS?

- approximately 56 percent of the cyanide added to the unsaturated column was oxidized to cyanate,
- approximately 10 percent of the cyanide added to the column was volatilized to HCN gas.

Thus, attenuation of cyanide by natural processes can be significant in a relatively short period of time.

Clay liners can be effective in containing and retarding cyanide movement. Projections from column tests subjected to a 3-foot hydraulic head indicated that two feet of compacted shale would contain weak-acid dissociable cyanide over the 10- to 20-year life of a facility ($R^2C^2$, 1989). This projection was calculated using an assumed compacted shale hydraulic conductivity of $10^{-7}$ cm/sec. Using this conductivity and a 3-foot hydraulic head, a solution penetration of about 8 inches per year was calculated ($R^2C^2$, 1989). However, the cyanide front had moved only slightly more than four inches after six pore volumes had passed through the column. At a solution penetration of 8-inches per year, it would require 18 years for six pore volumes to migrate through a 24-inch thick liner. Since the underdrain at the Escalante site kept the hydraulic head to a minimum (Fox, 1984), the wetting front and cyanide front would be much slower.

## 6. CONCLUSIONS

As was the case with the Fox report in 1984, model predictions from the current study over estimate the rate of seepage into the clay liner and foundation soils. Observed conditions at the Escalante site showed that the wetting front had penetrated no more than 3 inches, if any, into the clay liner after 14 months under a saturated depth of 10 feet. Model predictions by GSA show the wetting front penetrating over 8 feet during this time. Thus, the results of this study appear to be very conservative with respect to downward movement of the wetting front.

Based upon the relatively isolated location of the tailings facility (i.e., the distance to downgradient wells), the unlikelihood of seepage from the pond (Fox, 1984), the great depth to the water table, the large time required for contaminants to move off-site (if they reach ground water), and the natural attenuation/degradation of cyanide, the likelihood of a significant impact of cyanide on the ground water system in the vicinity of the Escalante site is very small.

## 7. REFERENCES

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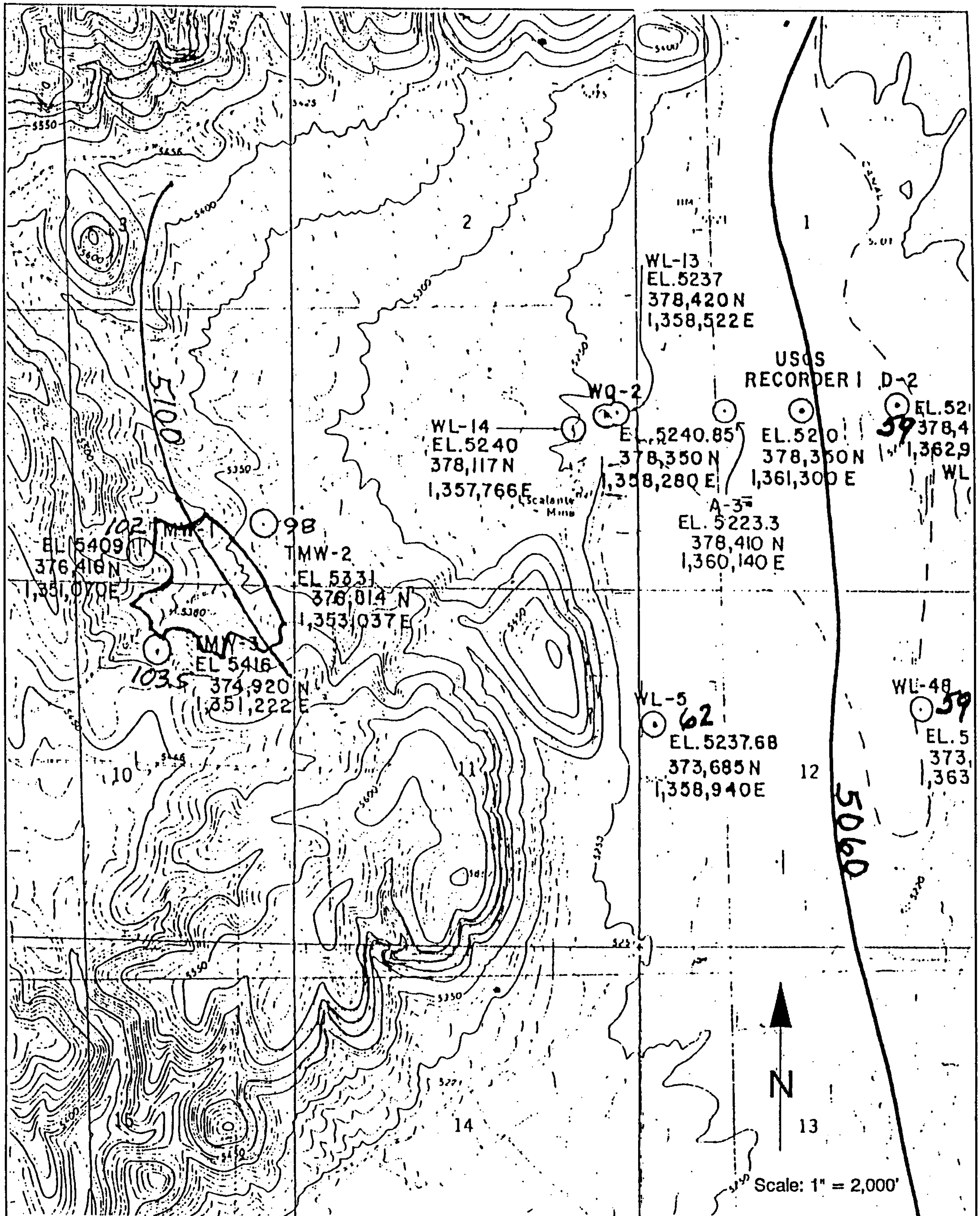


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Figure 1
September 1990 Ground-Water Contours

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Mine Permit Number M021 0004 Mine Name Escalante Silver
Operator Hecla Mining Co Date September 13, 1991
TO ________________ FROM ________________

__CONFIDENTIAL __BOND CLOSURE __LARGE MAPS X EXPANDABLE
__MULTIPUL DOCUMENT TRACKING SHEET __NEW APPROVED NOI
__AMENDMENT _OTHER ________________

Description YEAR-Record Number

__NOI X Incoming __Outgoing __Internal __Superceded

Groundwater Permit for Tailings Pond

__NOI __Incoming __Outgoing __Internal __Superceded

__NOI __Incoming __Outgoing __Internal __Superceded

__NOI __Incoming __Outgoing __Internal __Superceded

__TEXT/ 81/2 X 11 MAP PAGES __11 X 17 MAPS __LARGE MAP

COMMENTS: ________________

CC: ________________